GNSS-SLR combination with co-location on satellites

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Overview

1. **Combination strategy**
   - Microwave GNSS observations
   - SLR observations to GNSS satellites
   - SLR observations to LAGEOS+ETALON

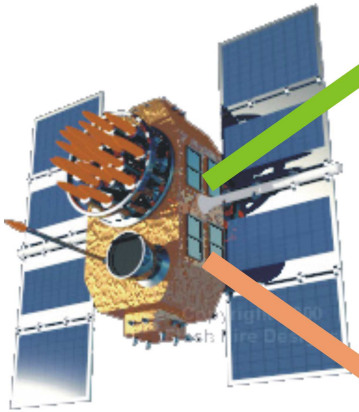
2. **Results** from combined GNSS-SLR analysis:

   → Geocenter coordinates

3. **2008 reference frame** and GNSS antenna **phase center** model

4. Conclusions

Combined GNSS-SLR analysis



Microwave observations

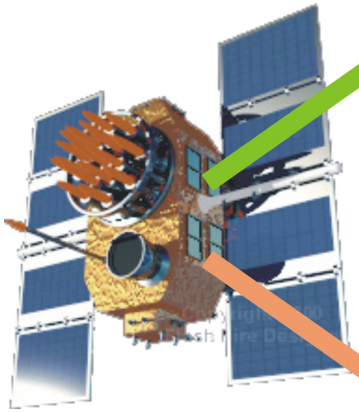
SLR range observations

Daily analysis

1d NEQ

7-day GNSS +SLR

Combined GNSS-SLR analysis



Microwave observations

SLR range observations

Daily analysis

1d NEQ

7-day GNSS +SLR

SLR range observations

Weekly analysis

7d NEQ

7-day GNSS + SLR + LAG / ETA

Combined GNSS-SLR analysis

Parameters estimated:

- Station coordinates (independent, i.e., no local ties)

- Earth Rotation Parameters
- Geocenter coordinates
- **Orbit parameters for GNSS satellites** (1-day arc)

Combination of GNSS – SLR: Satellite co-location

- Orbit parameters for LAGEOS / ETALON (7-day arc)

- Offsets of the **Laser Reflector Arrays** (LRAs)
- Offsets of the **microwave satellite antenna** (SAO)
- SLR **range biases**

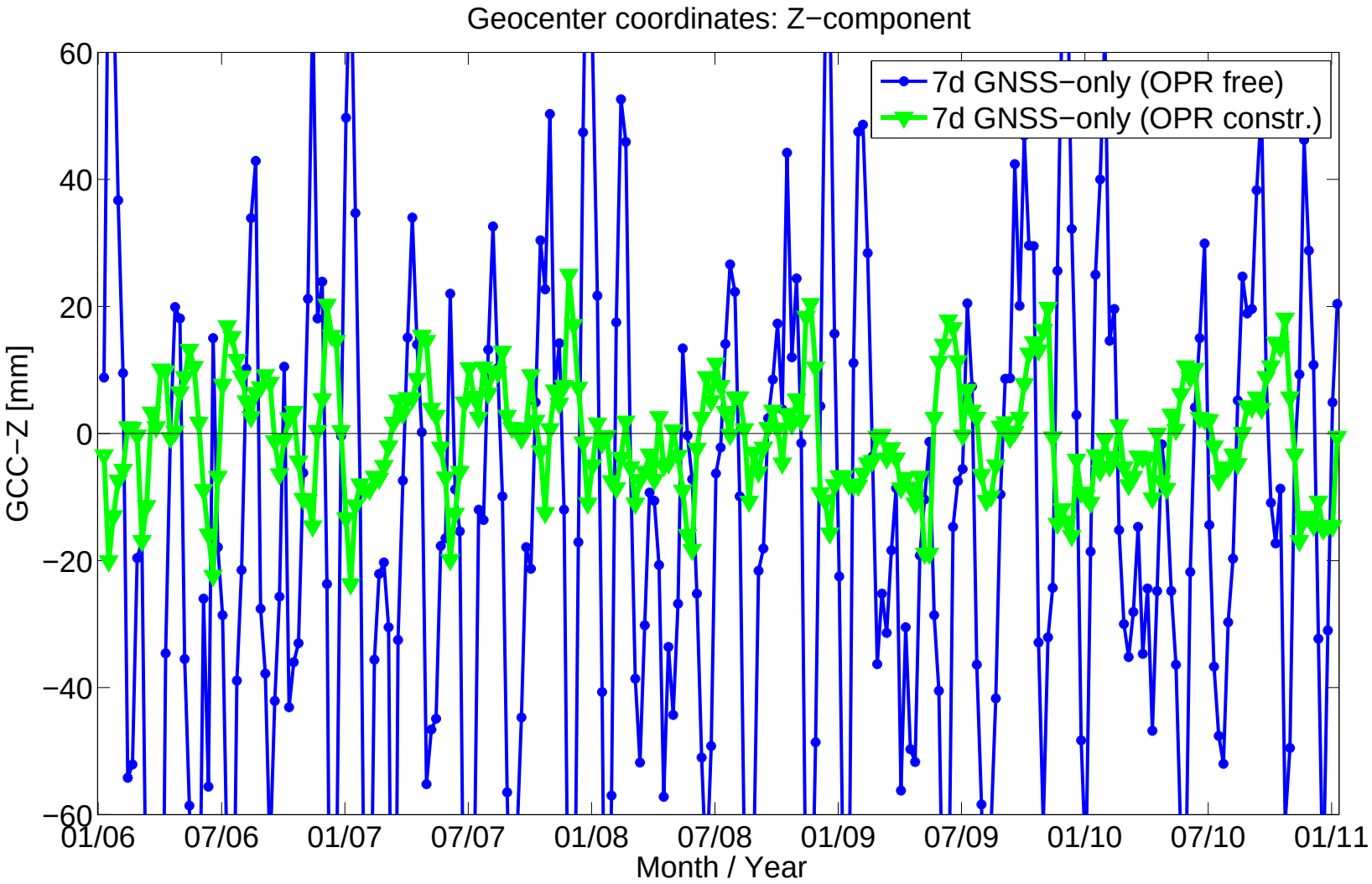
Estimate in multi-year solution ⇒ Introduce into weekly solutions

Geocenter: GNSS-only

Once-per-Revolution (OPR) orbit parameters needed for modelling radiation pressure

BUT: Correlation of OPR parameters with **geocenter coordinates**

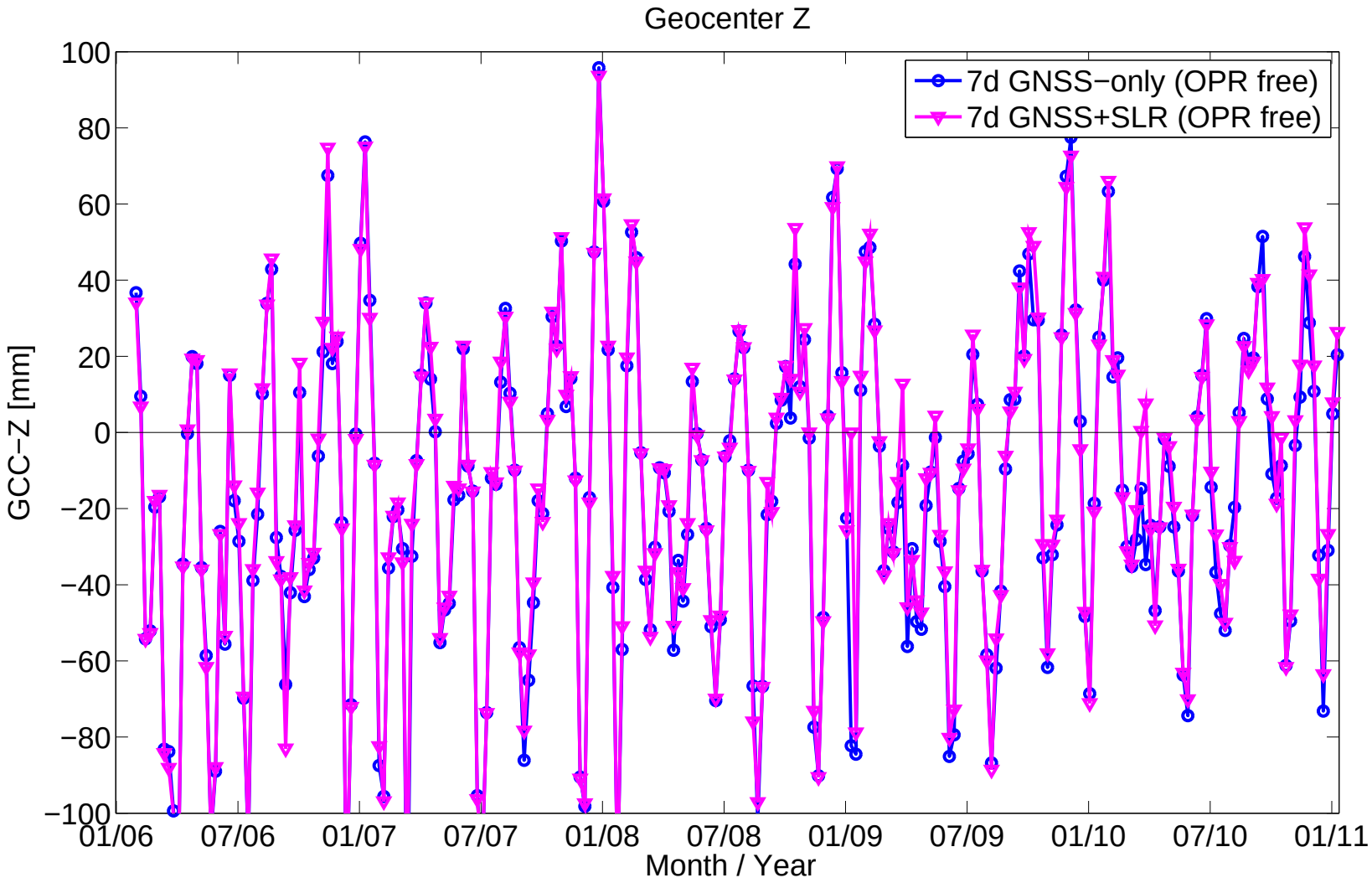
⇒ **2 OPR** parameters have to be **constrained** in GNSS solutions



Geocenter: GNSS + SLR

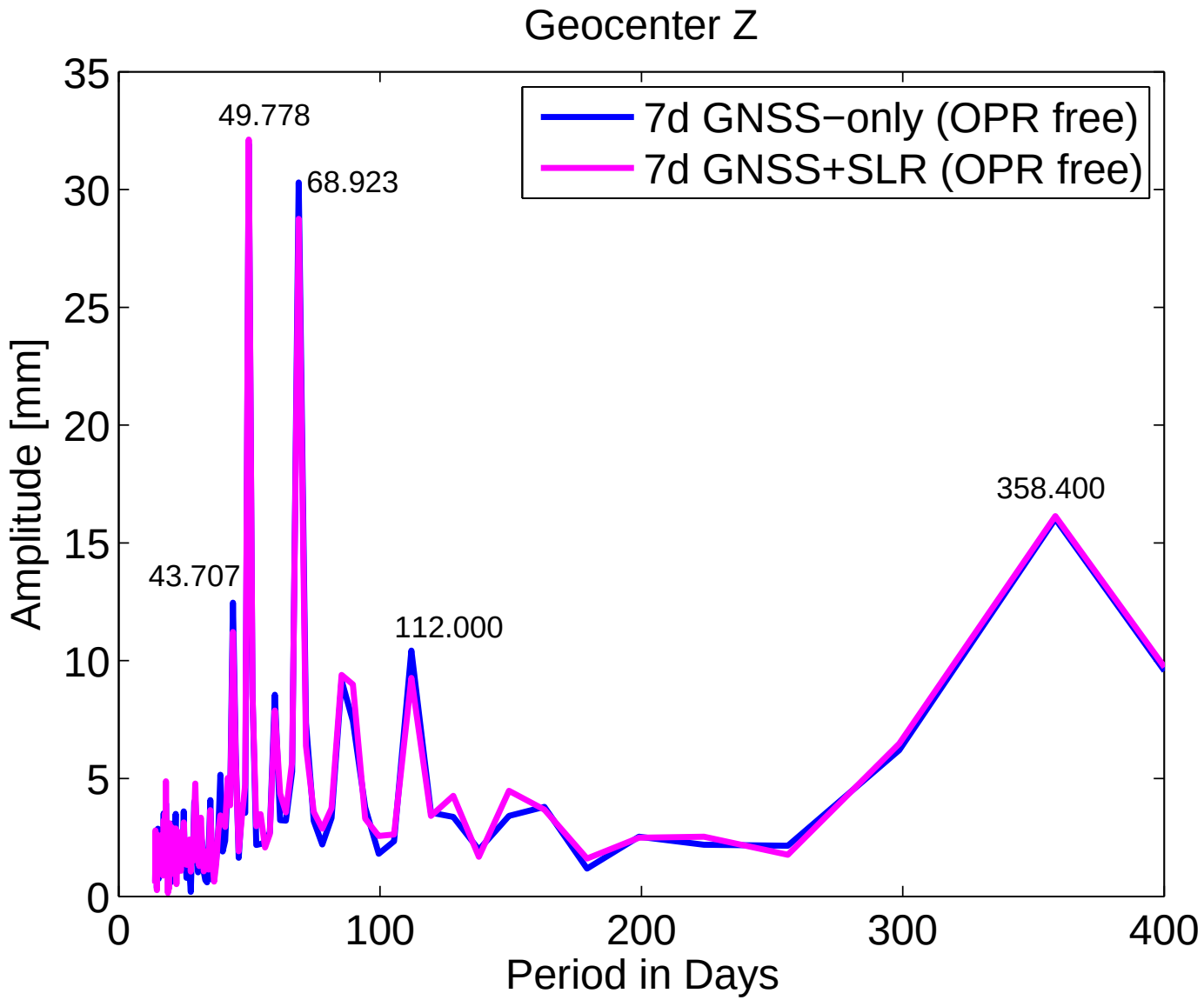
Can the **combination with SLR to GNSS** improve the geocenter estimation?

No impact!



Geocenter: GNSS + SLR

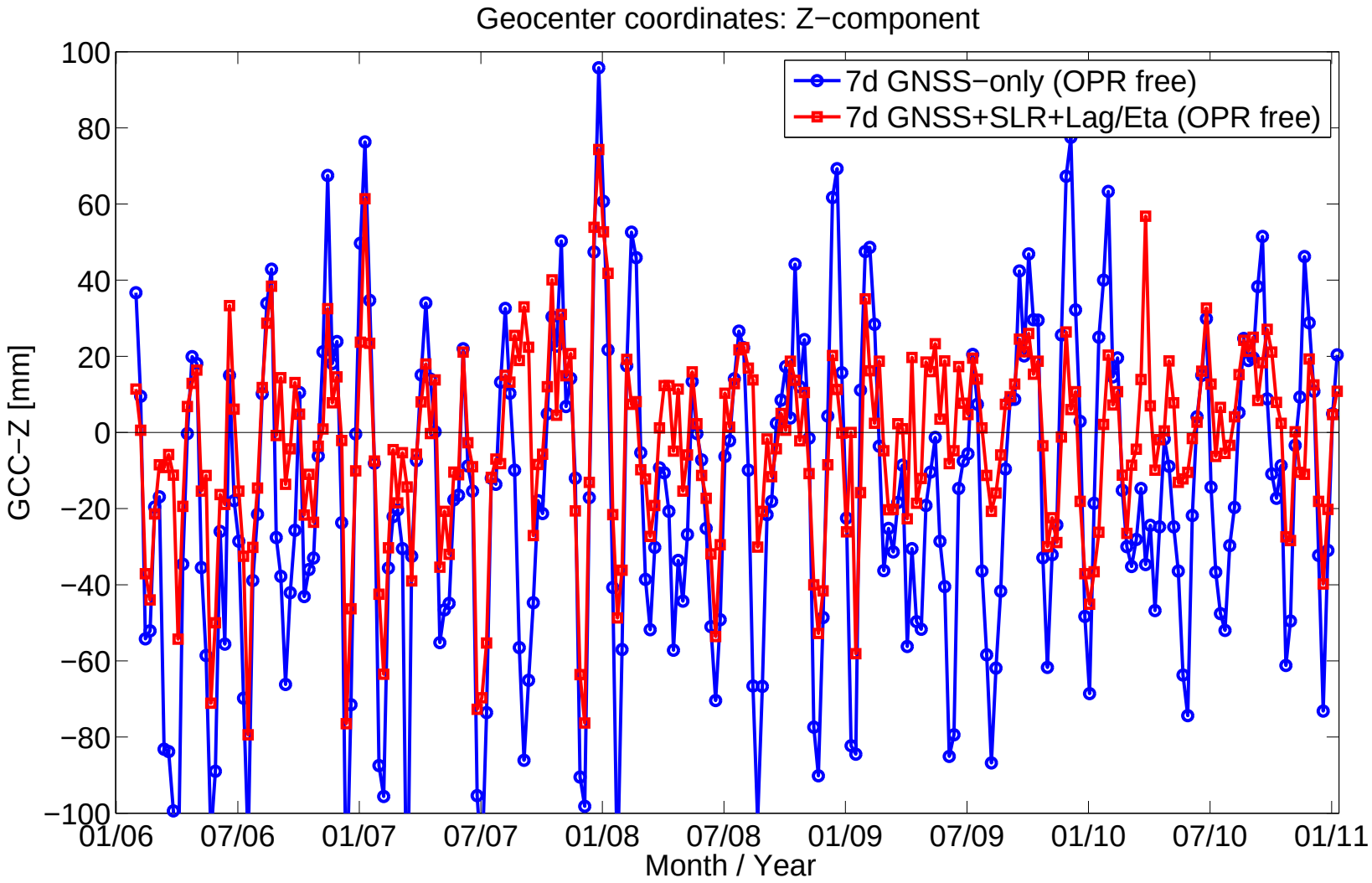
Can the **combination with SLR to GNSS** improve the geocenter estimation? **NO!**
It's a matter of the **orbit modelling** and **NOT** a question of the **observation technique.**



Geocenter: GNSS + SLR + Lageos/Etalon

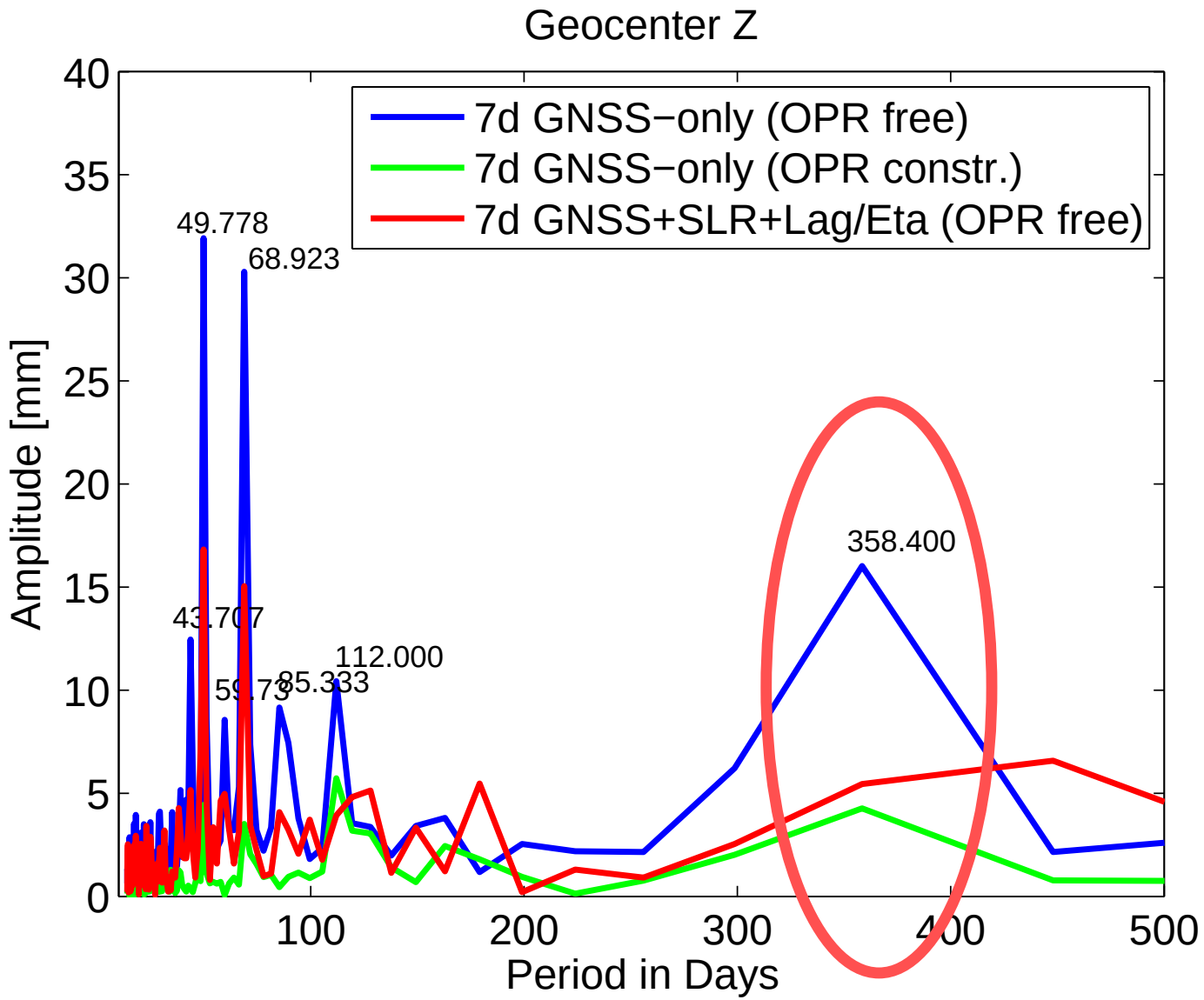
Can the **combination with SLR to LAGEOS/ETALON** improve the geocenter estimation?

RMS reduced from **43.2 mm** to **25.0 mm**



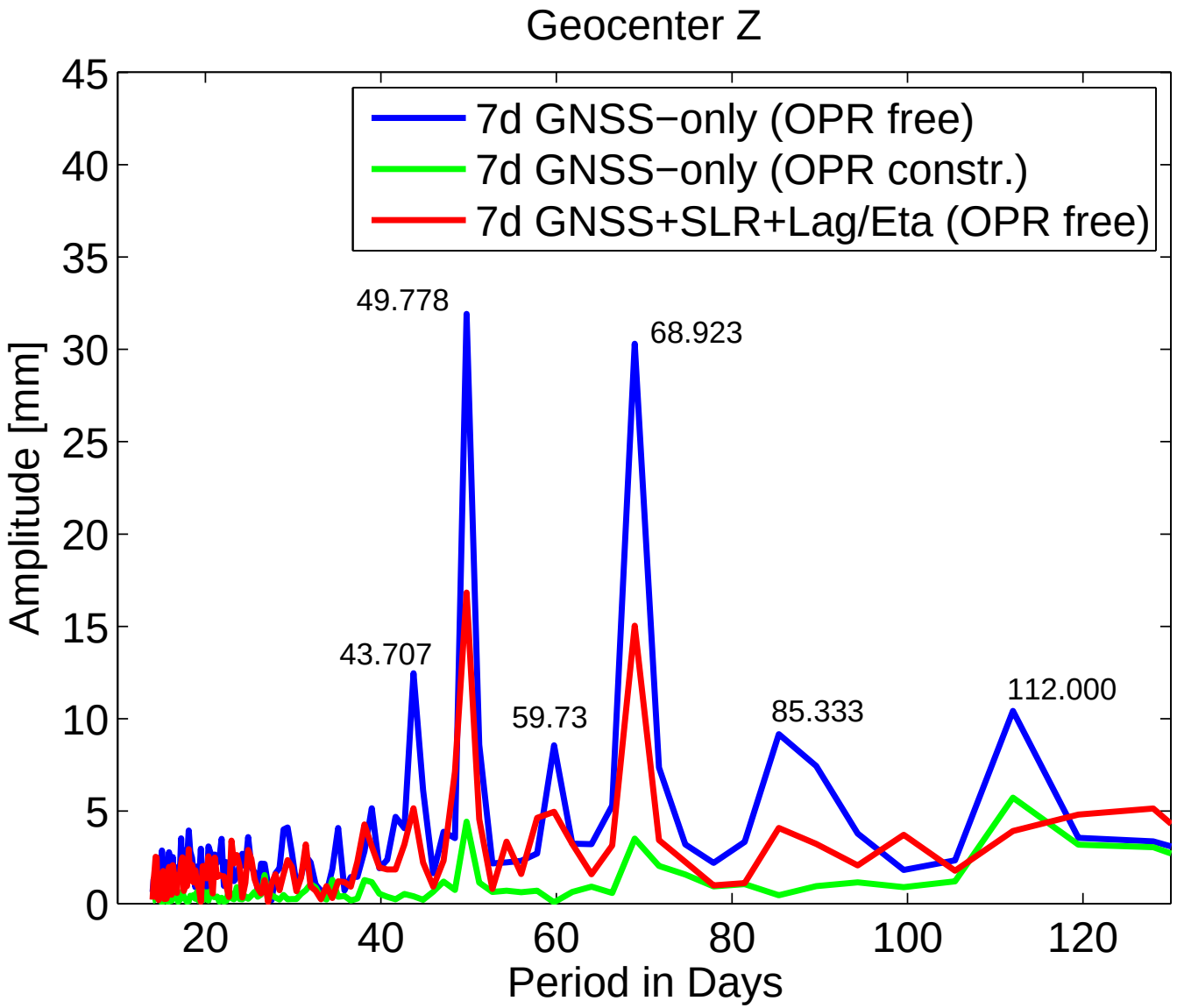
Geocenter: GNSS + SLR + Lageos/Etalon

The **amplitude vanishes** for the frequency of the **draconitic GPS year**
(similar to constraining OPR parameters in GNSS-only solution)



Geocenter: GNSS + SLR + Lageos/Etalon

The **amplitudes are reduced** for most of the **sub-frequencies** of the draconitic GPS year, but they are still present.



2008 reference frame / antenna model

Does IGS08 / SLRF2008 and igs08.atx improve the consistency between GNSS and SLR?

→ Test for 1 year of data (2010)

PRN	# SLR NP	Mean Bias [mm]			RMS of residuals [mm]		
		„2005“	„2008“	Δ	„2005“	„2008“	Δ
R08	9769	-31.9	-34.1	2.2	38.7	31.1	-7.6
R15	9139	-14.7	-14.1	-0.6	41.3	33.1	-8.2
R23	4615	-22.1	-22.9	0.8	38.9	29.7	-9.2
R11	4553	-27.3	-29.4	2.1	48.4	42.0	-6.4
G06	3533	-32.2	-33.4	1.2	30.6	26.6	-4.0
R05	2201	-8.4	-13.6	5.2	35.0	26.7	-8.3
R18	1830	-15.3	-16.8	1.5	37.2	25.6	-11.6

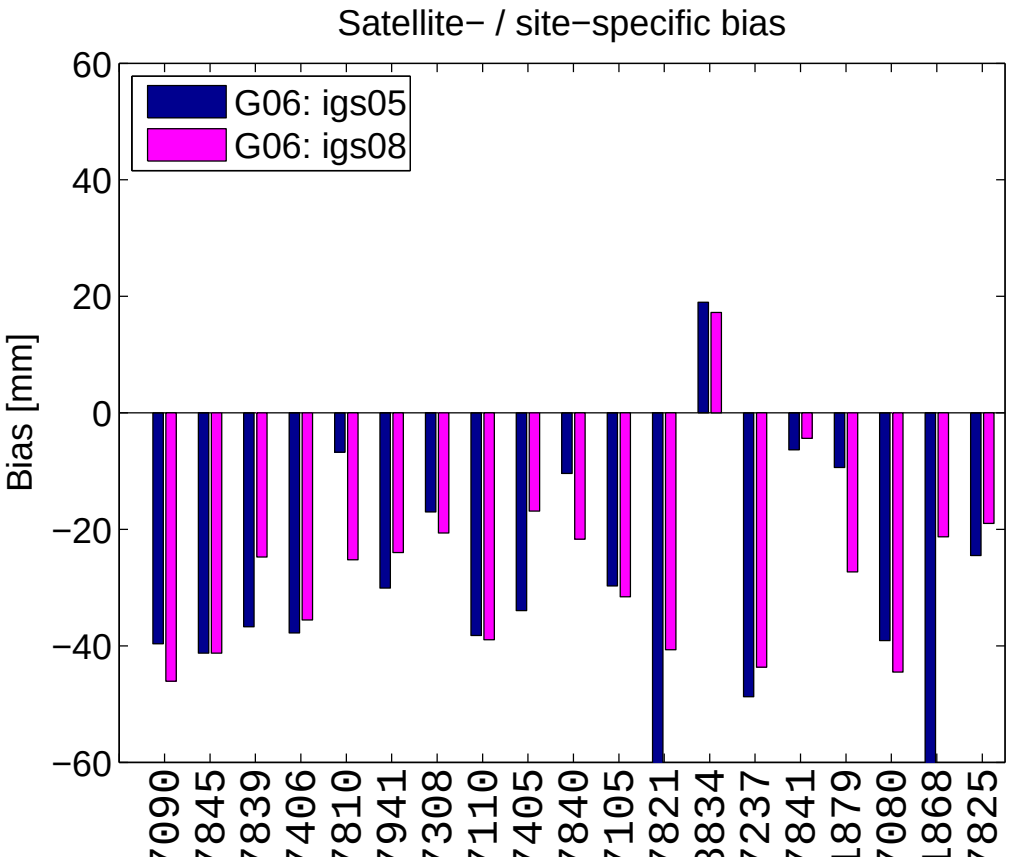
~20% improvement

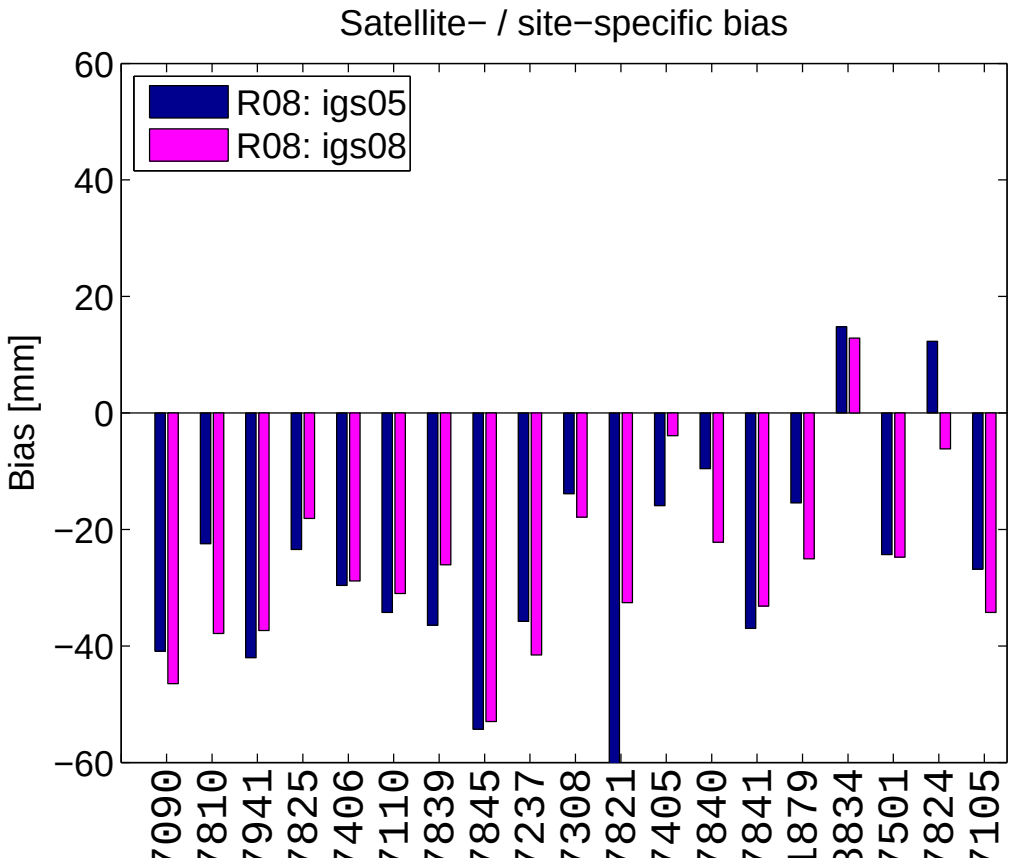
2008 reference frame / antenna model

Mean bias is **station-dependent**:

→ Smaller bias for “2008” models: most of the stations

→ Larger bias for „2008“ models: Yarragadee and Zimmerwald





Conclusions

- ***Geocenter of GNSS*** cannot be improved by combining only with ***SLR data to GNSS*** satellites

- ***Geocenter*** can be improved by adding ***SLR to spherical satellites***
  But: Draconitic GPS/GLONASS period still present

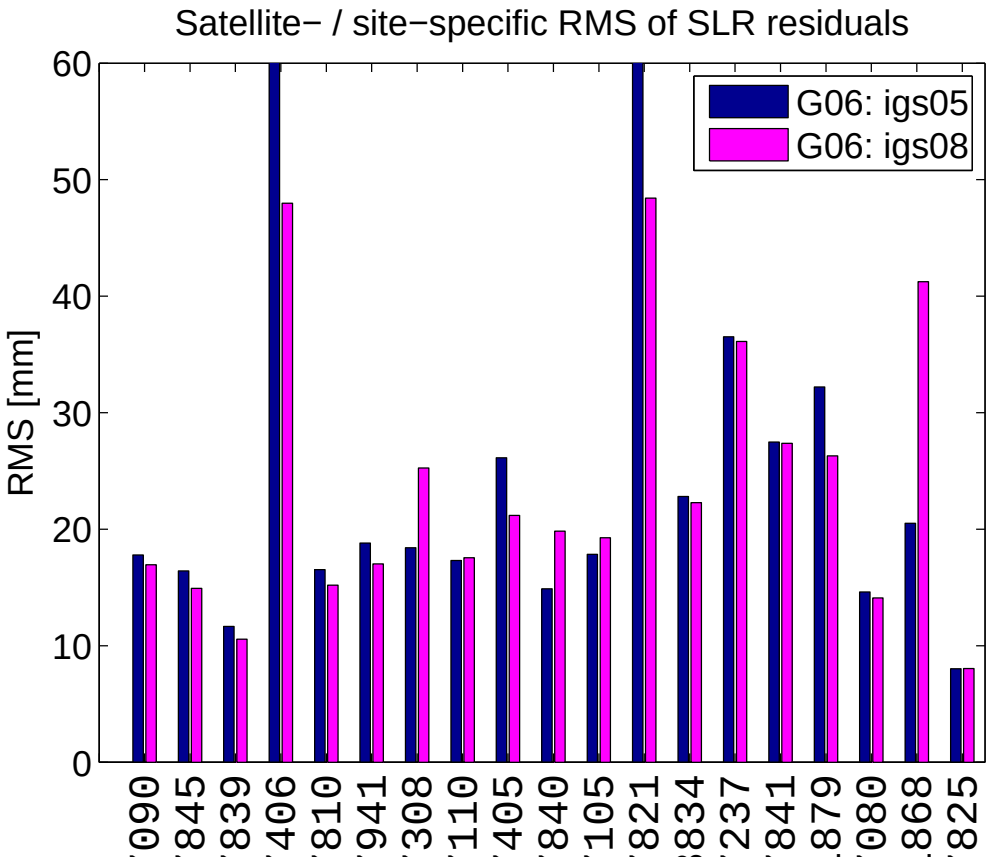
→ Add lower spherical satellites (Starlette, Stella)
→ Give higher weight to SLR observations?
→ Improve GNSS orbit modelling
(albedo, solar radiation pressure, antenna phase center)

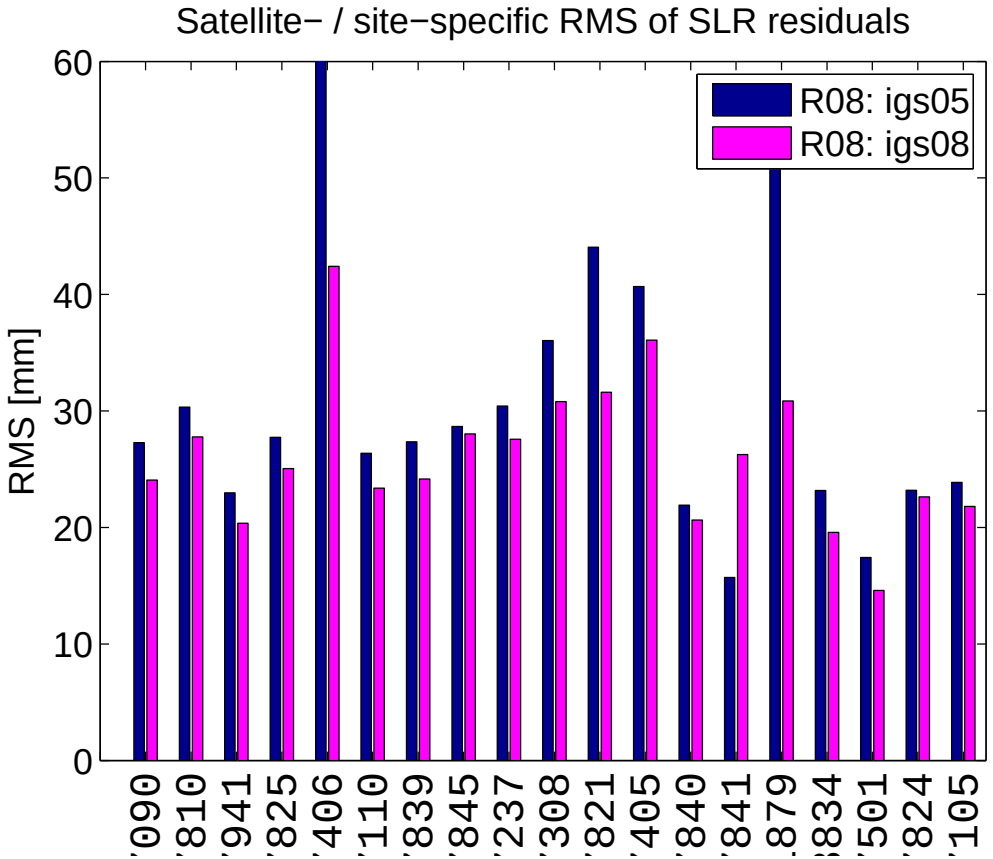
ITRF2008 and igs08.atx:

- ***RMS consistency*** GNSS-SLR improved by ~20%
- ***Station-specific bias*** decreased for most of the sites
- ***Mean bias*** GNSS-SLR is still at the level of a ***few centimeter***

2008 reference frame / antenna model

RMS is **station-dependent**:
→ Smaller RMS for “2008” models: almost all stations



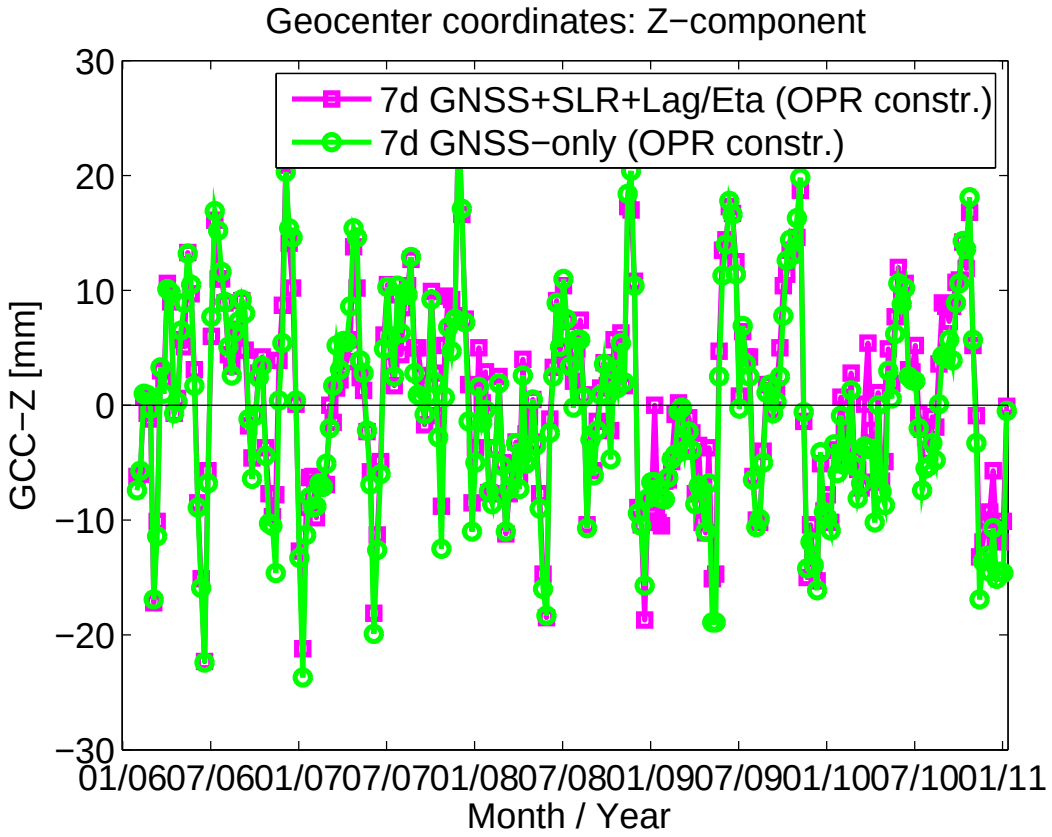


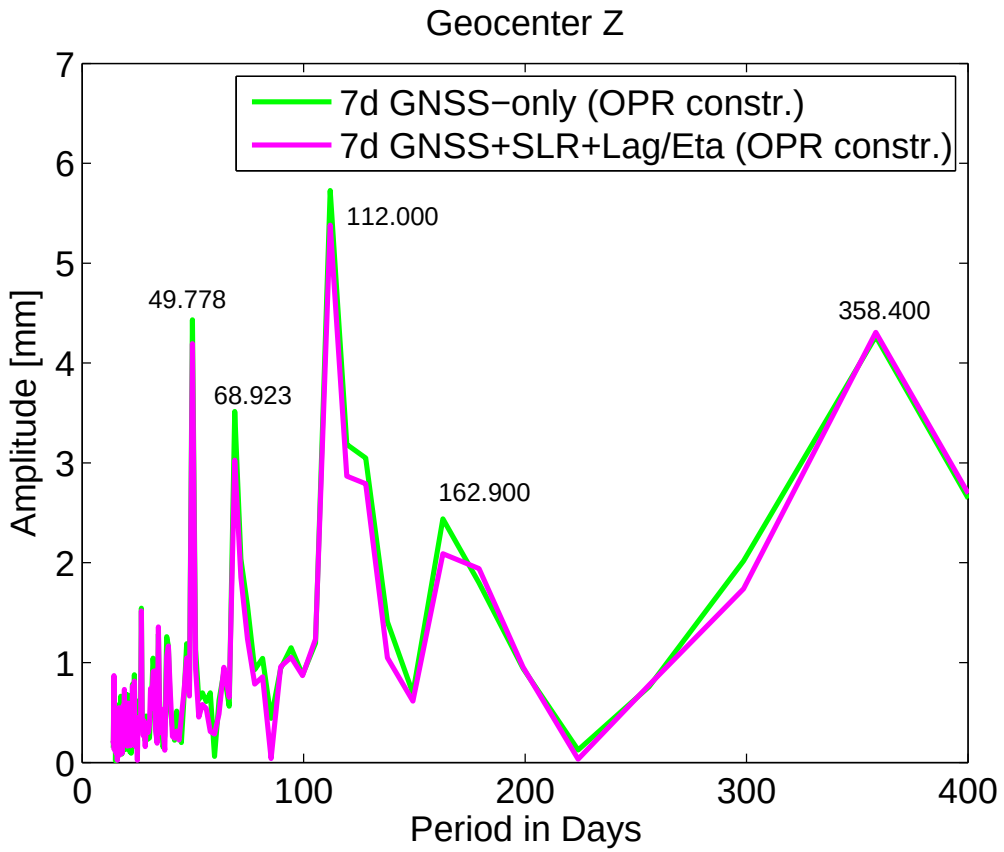
Geocenter: GNSS + SLR + Lageos/Etalon

If the **OPR** orbit parameters are **constrained**:

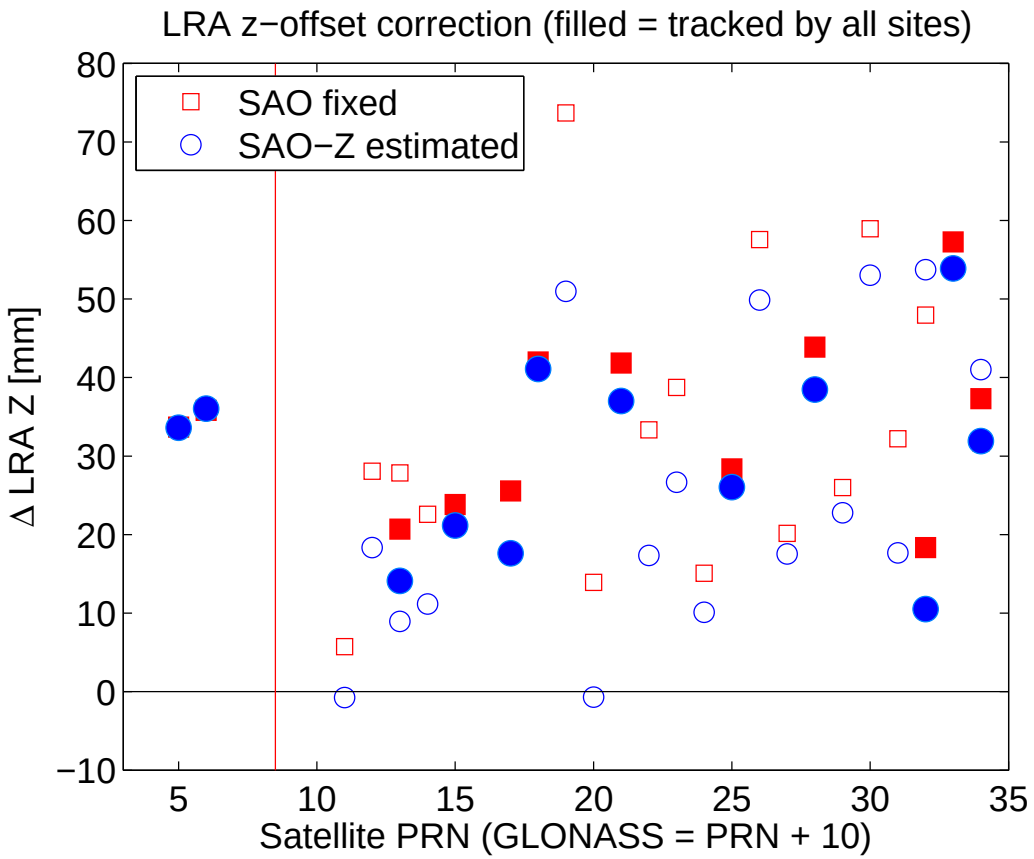
LAGEOS has **almost no impact** on the **geocenter**.

RMS is slightly reduced from **9.2 mm** to **8.5 mm**





LRA offset corrections



Mean correction:

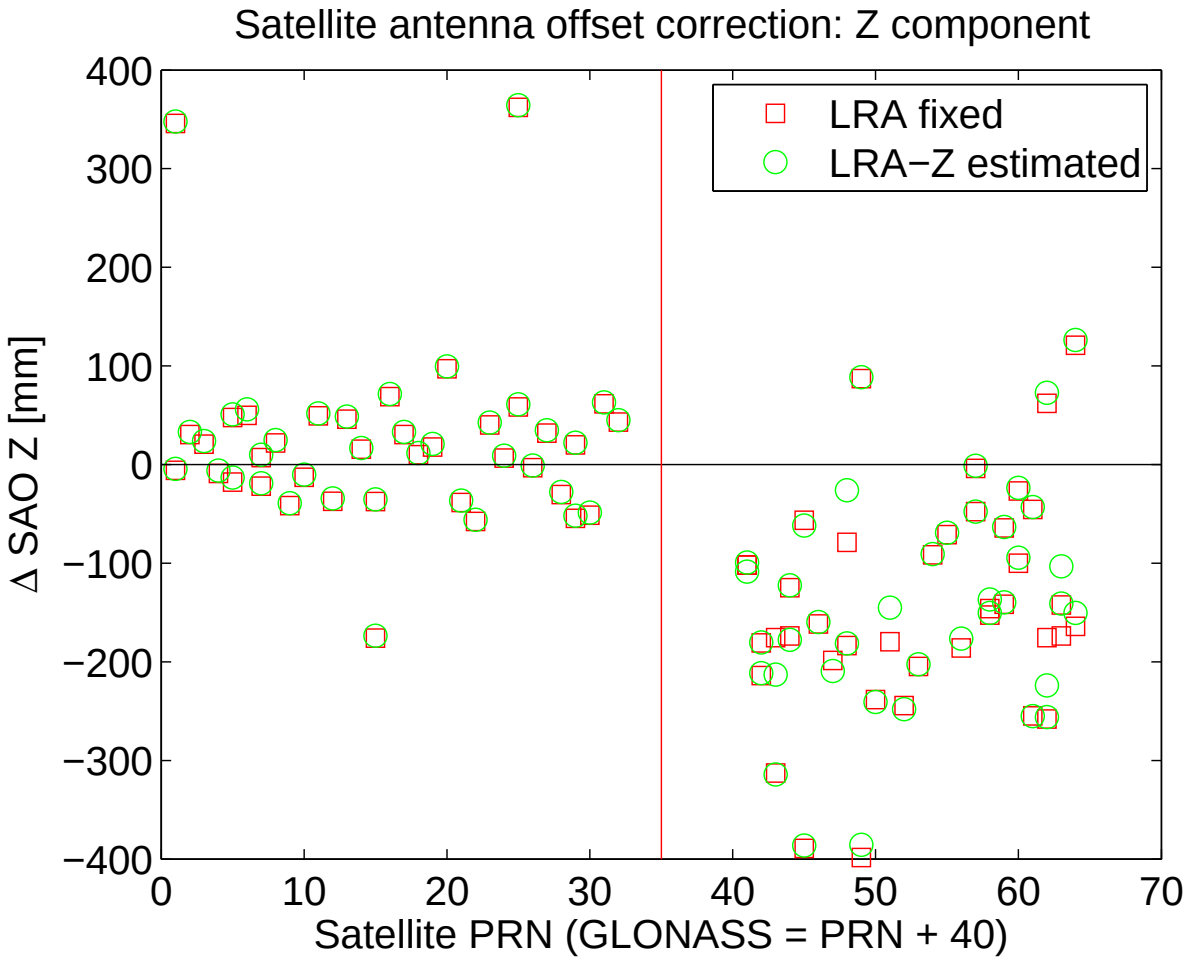
	GPS	GLONASS
SAO fixed	34.76 mm	33.56 mm
SAO-Z estimated	34.83 mm	26.52 mm
⇒ **Difference**	**0.06** mm	**7.04** mm

***Filled signatures*:**
Satellites **tracked by all SLR sites**

***Others*:**
Satellites tracked only by
Herstmonceux (since Dec. 2009)

⇒ Significant corrections to LRA offsets
⇒ Estimation of SAO has almost no impact

GNSS SAO corrections



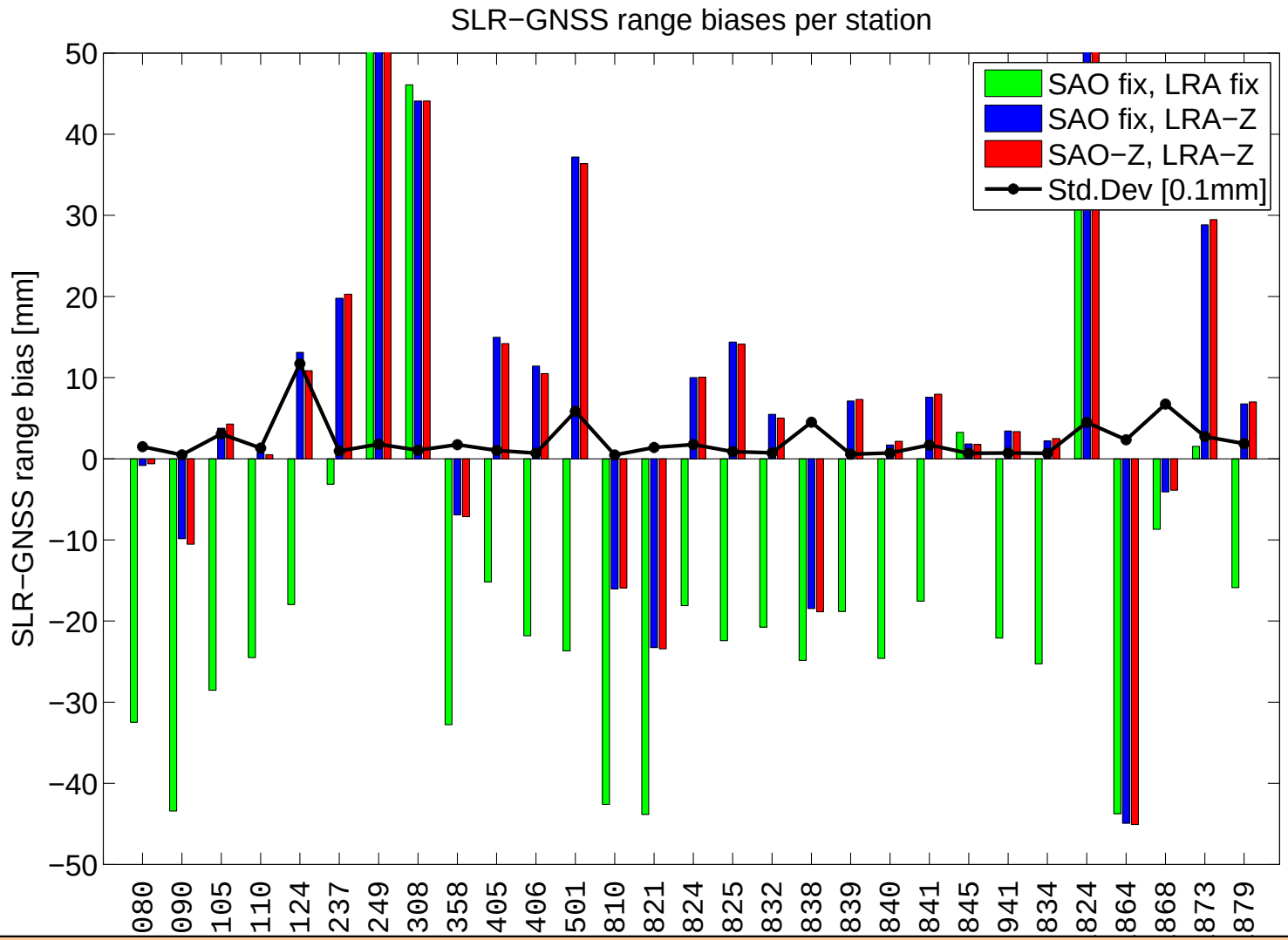
⇒ Significant corrections to SAO of igs05.atx

⇒ Common estimation with LRA corrections is possible

Mean correction:

	GPS	GLONASS
LRA fixed	23.34 mm	-142.35 mm
LRA-Z estimated	25.93 mm	-138.80 mm
⇒ **Difference**	**2.59** mm	**3.55** mm

SLR-GNSS „range“ biases

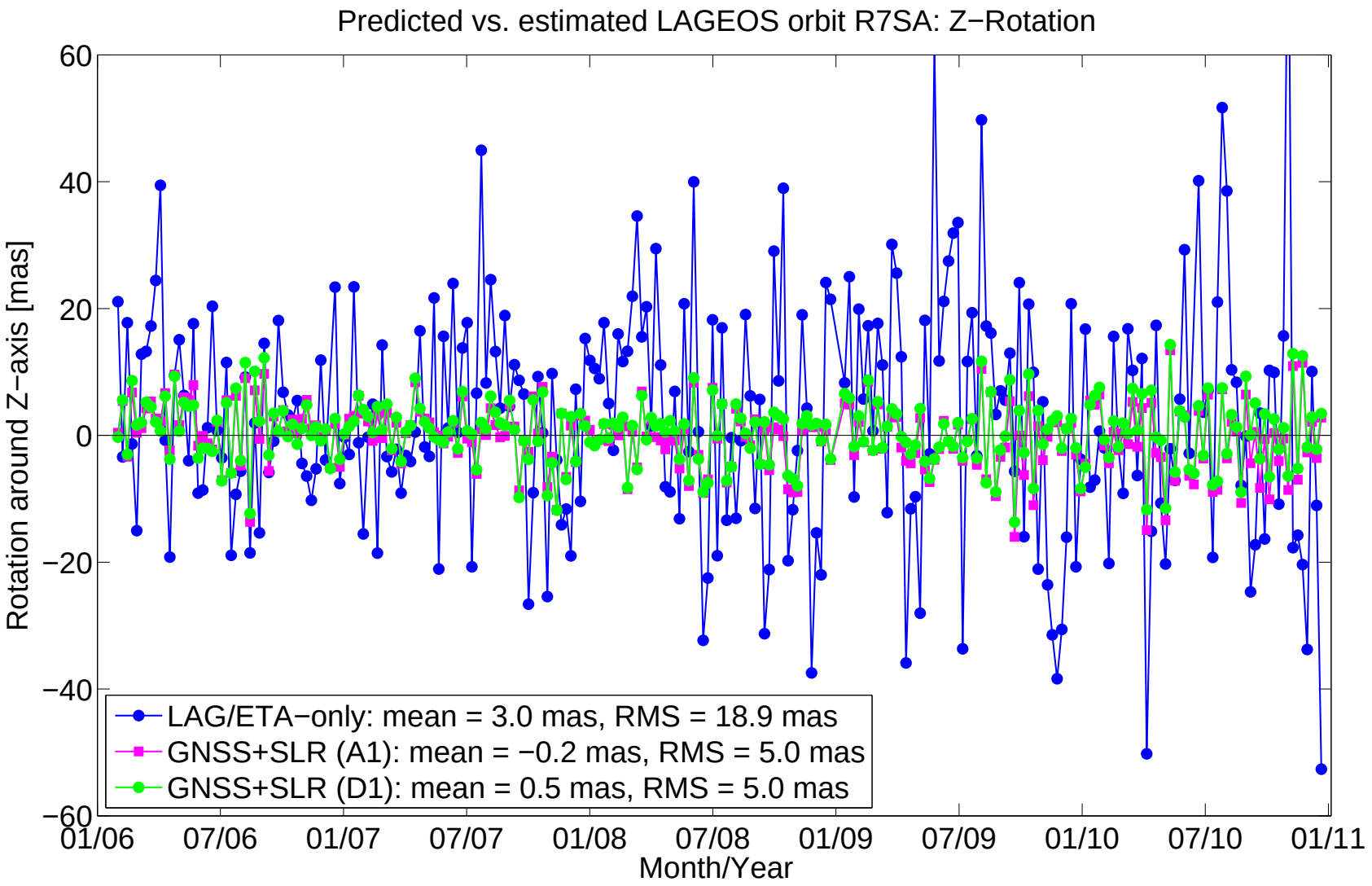


Common estimation of: GNSS Satellite Antenna Offset (*z*-direction)
LRA offset (*z*-direction)
GNSS-SLR **range** biases

LAGEOS orbits

Orbit prediction for the following week:

Orientation is improved (z-axis)



Geocenter: GNSS-only

Sub-frequencies of the **draconitic year** (~352 d) are visible in the spectra of geocenter coordinates if **OPR are estimated without constraints**

Constraining OPR reduces the amplitudes